Hemodialysis Vascular Access: Core Curriculum 2025

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The majority of patients with kidney failure requiring replacement therapy will need the support of hemodialysis during their journey with kidney failure. A reliable functioning vascular access is required to provide hemodialysis. This Core Curriculum reviews the major forms of vascular access (arteriovenous fistula, arteriovenous graft, and central venous catheter) as well as the planning, preparation, creation, use, and maintenance of vascular access, requiring a P-L-A-N (*P*atient ESKD *L*ife-Plan first then *A*ccess *N*eeds) for each patient. The end-stage kidney disease Patient Life-Plan focuses on a strategy for kidney replacement modalities, while the Access Needs are the corresponding dialysis access(es) and management plans. The Access Needs include a vessel preservation plan, creation plan, contingency (complications) plan, and access succession plan. Stenosis and thrombosis are common problems with arteriovenous accesses, and dysfunction and infection are common problems with central venous catheters. Underrecognized and underreported but potentially life-threatening situations include arteriovenous access rupture and high-output cardiac failure. Effective management of these and other vascular access problems requires a coordinated multidisciplinary effort that is patient centered while preserving vascular access.

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The Core Curriculum aims to give trainees in nephrology a strong knowledge base in core topics in the specialty by providing an overview of the topic and citing key references, including the foundational literature that led to current clinical approaches.

Introduction

Chronic kidney disease (CKD) affects >10% of the population worldwide, impacting >850 million individuals. In 2020 there were 130,522 incident and 807,920 prevalent patients with end-stage kidney disease (ESKD) or kidney failure requiring kidney replacement therapy (KFRT) in the United States. Most individuals required dialysis, and 22% were sustained with a kidney transplant. Of those patients requiring dialysis, hemodialysis (HD) accounts for almost 90%. In this installment of *AJKD*'s Core Curriculum in Nephrology, we review the hemodialysis vascular access which is needed to establish a connection between the patient's circulation and the HD machine. The 2 main categories of vascular access are the arteriovenous access (AV access) and central venous catheter (CVC). AV access refers to arteriovenous fistula (AVF) or arteriovenous graft (AVG).

Vascular Access Planning and Preparation

Case 1: *A 26-year-old schoolteacher is seen in a follow-up visit for CKD secondary to membranoproliferative glomerulonephritis. She also has hypertension and inflammatory bowel disease, with a recent severe flare that required temporary ileostomy. She has been cared for by a CKD clinic since her CKD diagnosis at 12 years old. She has a single parent who has diabetes and hypertension and a healthy younger brother. She is fatigued after work but denies symptoms of uremia or volume overload. Her medications include an angiotensin-converting enzyme inhibitor, calcium channel blocker, phosphate binder, budesonide, and statin. She has a body mass index of 29, blood pressure of 137/74, heart rate of 72 beats per minute. Her serum creatinine is 327 μmol/L (3.7 mg/dL), estimated glomerular filtration rate (eGFR) is 17 mL/min/1.73 m^2, and urinary albumin-creatinine ratio (UACR) is 67 mg/mmol (593 mg/g). She asks you about the next steps toward kidney replacement therapy and dialysis access.*

Question 1: Our schoolteacher's ESKD Life-Plan should ideally include input from the following people:

(a) The patient
(b) The patient's parent
(c) The nephrologist
(d) The patient and relevant supporters including a vascular access surgeon and nephrologist

For the answer to this question, see the following text.

ESKD Life-Plan

Foundational for dialysis access is the ESKD Life-Plan, which is an individualized strategy for living with ESKD introduced in the 2019 Kidney Disease Outcomes Quality Initiative (KDOQI) Vascular Access Guidelines. The ESKD Life-Plan, developed between patients and their care management team, is a personalized road map of kidney replacement modalities—HD,

SHOUT
SHARE
IT

peritoneal dialysis (PD), and kidney transplant—and related dialysis accesses for the lifetime of the patient, which means the answer is (d). Importantly, the Life-Plan considers the patient's medical and vascular access circumstances and patient preferences, including a need for contingency plans (ie, plans for potential future vascular access complications) and succession plans (ie, plans for the next dialysis accesses).

The P-L-A-N is an acronym for "Patient ESKD Life-Plan first then *A*ccess Needs," and influences most decisions made about dialysis access. It directly impacts the patient and their potential access creations/insertions and any complications that may incur with vascular access management. Each patient's ESKD Life-Plan should be documented in the medical record, updated regularly, and referred to when making decisions about type of dialysis access and the treatments related to dialysis access.

Case 1, continued: Our schoolteacher has been cared for by a CKD clinic for many years, and the trajectory of her GFR decline has been followed closely to enable timely planning and preparation for vascular access. Discussions about the Patient ESKD Life-Plan should be initiated when a patient with CKD has an eGFR of ≤30 mL/min/1.73 m^2, and referral for vascular access assessment should occur when the eGFR is 15-20 mL/min/1.73 m^2 with concurrent progressive decline in kidney function. Planning for Access Needs (creation, contingency, succession, and vessel preservation plans) are appropriate for all patients with CKD progressing to a need for HD, failing PD, failing transplant, and prevalent patients requiring HD with a failing AV access or CVC. Our patient has active inflammatory bowel disease, and she is not currently a PD candidate.

After much discussion with her nephrologist and health care team, she decides that her ESKD Life-Plan will be (1) home HD; (2) living-related kidney transplant; and (3) PD (by then hopefully her inflammatory bowel disease will be inactive and stable; an ESKD Life-Plan is designed to be regularly re-evaluated). Given her independence and lifestyle, home HD would give her the best modality to achieve her current goal to maintain her status quo as much as possible. Her likelihood of reaching KFRT is high (estimated to be 57% in 2 years by KFRE; www.kidneyfailurerisk.com).

She has hesitated to initiate the workup for a kidney transplant because her single parent is ineligible due to comorbidities and she did not want to ask her younger sibling. She is aware that the PLAN is easily modifiable with changes in her circumstances and will be reviewed annually. She has been educated about "saving her veins" (www.saveyourvein.org) and has been getting venipunctures from the back of her hand since her eGFR was 30 mL/min/1.73 m^2. She knows that even after she receives her kidney transplant, she will need to continue protecting her central and peripheral veins due to the high likelihood of needing HD multiple times in her lifetime, given her young age and expected life span.

Question 2: What component of the Access Needs (also known as Access Plan) did our patient initiate first?

(a) Creation and succession plans to take into account who creates the vascular access, when, where, and how it is created, and what the future vascular access options are
(b) Cosmesis plan to ensure that her vascular access looks good
(c) Contingency plan (also known as complications plan) to consider all the possible complications of her vascular access, and what the options are for prevention, mitigation, and management of such complications
(d) Vessel preservation plan to protect her vessels for future vascular access since her eGFR fell below 30 mL/min/1.73 m^2 so that she has many vascular access options

For the answer to this question, see the following text.

Access Needs: Choosing AV Access

Once her ESKD Life-Plan has been determined, the patient in Case 1 will establish her access plan (ie, Access Needs). The creation plan is composed of many elements that help determine her "lifeline": the type of vascular access to be created, who creates it, how it is created, and when and where it is created. However, the ability to have vascular access depends on the patient having viable vessels to create AV access, so protecting and preserving vessels in a patient with CKD is essential, so the answer is (d). An AVF, created by an anastomosis between a native artery and a vein, is the recommended vascular access for patients requiring HD due to its substantially lower rates of thrombosis, infection, and health care–related expenditures compared with AVG and CVC, if the AVF successfully matures for dialysis use. However, many AVFs do not mature successfully to support dialysis and will need interventions to assist with maturation. Studies have demonstrated that AVFs that need multiple interventions before use (eg, recurrent angioplasties to correct stenosis, ligations for collateral veins to divert flow from a maturing AVF, etc) have a lower cumulative patency (ie, AV access patency from creation to abandonment) than AVFs that do not need such interventions. For this reason, choosing a vascular access type that can be used with minimal interventions and that concurrently preserves vessels for future needed access is critically important.

Table 1 lists the risk factors for AVF maturation failure. In select patients (Table 1), vessel mapping can help the operator and vascular access team determine whether an AVF is feasible and, if so, the optimal type for the patient's situation (Fig 1). The key variables to consider with vessel mapping include who conducts and interprets it (eg, technician or surgeon creating AV access), the degree of patient's residual kidney function (ie, if present, may limit the use of venography and contrast dye in order to preserve kidney function), and the anatomy to be interrogated (eg, central veins are typically not clearly visualized with duplex ultrasound). Intraoperative mapping by the operator can influence the type of AV access created and outcomes. After AV access creation, duplex ultrasound at 2 weeks may be helpful in the early identification of AVFs that do not develop adequately and should be closely monitored and

Table 1. Clinical Situations and Characteristics Where Vessel Mapping May Be Helpful

Clinical Situation	Risk Factors
Fistula failure	Older age, female, peripheral vascular disease, heart failure, small pediatric vessels
Iatrogenic peripheral vessel damage	Antecubital venipunctures, PICC insertion, radial artery access for coronary interventions, invasive hemodynamic monitoring, radial artery harvesting for CABG surgery
Patient-related vessel abnormality or damage	Vasculitis, IV drug use
Central vein stenosis or occlusion	Prolonged CVC or port use, multiple CVC insertions, pacemaker, ICD, PICC, surgery to neck, chest, upper extremity
Limitations to physical exam	Patient: refusal for exam, morbid obesity, dehydration (patient should be adequately hydrated at the time of exam) Environment: cold room

Based on information in Table 7.2 of: Lok CE, Huber TS, Lee T, et al. KDOQI clinical practice guideline for vascular access: 2019 update. *Am J Kidney Dis*. 2020;75(4)(suppl 2):S1-S164. doi.org/10.1053/j.ajkd.2019.12.001
Abbreviations: CABG, coronary artery bypass graft; CVC, central venous catheter; ICD, implantable cardioverter-defibrillator; IV, intravenous; PICC, peripherally inserted central catheter.

intervened on as needed to facilitate maturation. An experienced HD nurse or cannulator can often determine by clinical examination when an AVF can be used for dialysis. The AVF should be palpable with a firm but compressible vein of adequate diameter caliber (which depends on patient's body size and is naturally smaller for pediatric patients), less than 4 mm from the skin surface, with a straight cannulation segment of at least 6-8 cm, a palpable thrill strongest at anastomosis, and a continuous bruit with both systolic and diastolic components.

Additional Readings

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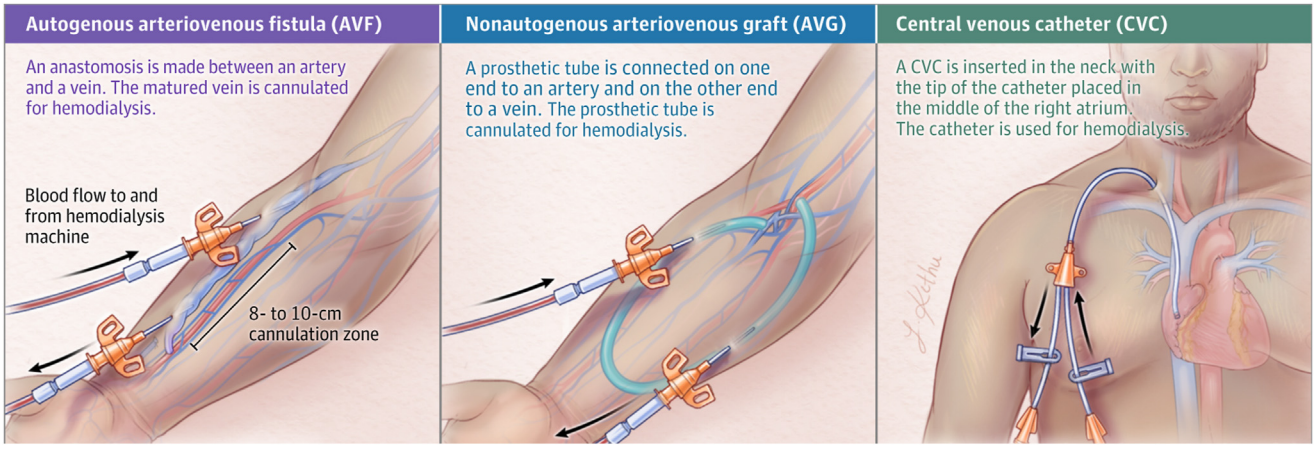
Autogenous arteriovenous fistula (AVF)
An anastomosis is made between an artery and a vein. The matured vein is cannulated for hemodialysis.
Blood flow to and from hemodialysis machine
8- to 10-cm cannulation zone
Nonautogenous arteriovenous graft (AVG)
A prosthetic tube is connected on one end to an artery and on the other end to a vein. The prosthetic tube is cannulated for hemodialysis.
Central venous catheter (CVC)
A CVC is inserted in the neck with the tip of the catheter placed in the middle of the right atrium. The catheter is used for hemodialysis.

Figure 1. Types of vascular accesses. Left panel: autogenous arteriovenous fistula. Middle panel: nonautogenous arteriovenous graft. Right panel: central venous catheter. Abbreviations: AVF, autogenous arteriovenous fistula; AVG, nonautogenous arteriovenous graft; CVC, central venous catheter. Image © 2024 American Medical Association; reproduced with permission of the copyright holder from Lok CE, Huber TS, Orchanian-Cheff A, Rajan DK. Arteriovenous access for hemodialysis: a review. *JAMA*. 2024;331(15):1307-1317. doi.org/10.1001/jama.2024.0535.

➢ Viecelli AK, Lok CE. Hemodialysis vascular access in the elderly—getting it right. *Kidney Int.* 2019; 96(1):37-47. doi:10.1016/j.kint.2018.09.016 ★ESSENTIAL READING

Access Needs: Indications for Catheter Use

Case 2: *A 71-year-old retired shop owner with long-standing uncontrolled diabetes, hypertension, peripheral vascular disease, CKD, and gout has presented with malaise, anorexia, fever, and cough. Laboratory testing reveals leukocytosis and a creatinine level of 548 µmol/L (6.2 mg/dL). His chest X-ray identifies a right lower lobe pneumonia, and a kidney ultrasound demonstrates small echogenic kidneys. Despite treatment of the pneumonia, his kidney function worsens, and he becomes oliguric. What are the immediate and longer-term vascular access options for this patient?*

In the United States, approximately 80% of patients initiate HD with a CVC. In situations of emergent or urgent need for dialysis, as in this case, a CVC (nontunneled or tunneled, depending on the situation) for temporary use is appropriate to manage intoxications, uremic symptoms, or volume overload refractory to medical management. Tunneled CVC inserted into the internal jugular vein is the most commonly placed for HD and should be inserted with imaging guidance to ensure the CVC tip resides in the mid right atrium. Nontunneled "temporary" CVC should be inserted under ultrasound guidance and should only be in place for 2 weeks to reduce the risk of catheter-related infection. There are valid circumstances for long-term use of tunneled CVC (Box 1); therefore, the terminology to designate AV access (AVF or AVG) as "permanent access" should not be used because CVC can also be used as permanent vascular access in select valid situations.

Box 1. Indications for Hemodialysis Central Venous Catheter Use

Short-term Use
- AVF or AVG created but not ready for use and hemodialysis is required
- Acute transplant rejection or other complications requiring hemodialysis
- PD patient with complications that require temporary use of hemodialysis
- Patient has a living donor transplant confirmed with a surgical date in the near future (eg, <90 days) and requires interim hemodialysis
- AVF or AVG complications (eg, major infiltration injury) that require temporary nonuse until problem is resolved

Long-term or Indefinite Duration
- Multiple prior failed AV accesses with no available options
- Valid patient preferences whereby use of AV access would severely limit quality of life or achievement of life goals
  - o Note: Patient would need to be properly informed of patient-specific risks and benefits of other potential and reasonable vascular access options.
- Limited life expectancy
- Absence of AV access creation options due to a combination of inflow artery and outflow vein problems or in infants/children with prohibitively diminutive vessels
- Special medical circumstances

Based on information in: Lok CE, Huber TS, Lee T, et al. KDOQI clinical practice guideline for vascular access: 2019 update. Am J Kidney Dis. 2020;75(4)(suppl 2):S1-S-164. doi.org/10.1053/j.ajkd.2019.12.001
Abbreviations: AVF, arteriovenous fistula; AVG, arteriovenous graft; AV access, arteriovenous access; HD, hemodialysis; PD, peritoneal dialysis.

CVC Complications

Poor Flows. The key complications with CVC use include CVC dysfunction, CVC-related infections, and central venous stenosis (discussed later). Both CVC dysfunction and infection can occur early or late from the time of insertion, and these separate complications may or may not be related. CVC dysfunction can occur due to mechanical factors, such as CVC malpositioning or kinks, and from intraluminal (thrombosis) and extraluminal (fibrin sheath coating) factors.

Treatment is typically with installation of a thrombolytic agent (eg, tissue plasminogen activator) using dwell or push techniques. If this is unsuccessful in restoration of flow, a central venogram may be performed to identify a fibrin sheath, which should be disrupted with balloon angioplasty; typically, a new CVC is required, which is usually inserted by guidewire exchange to preserve sites. Prevention is based on anticoagulant interdialytic locking (typically heparin or low-concentration 4% trisodium citrate) and use of thrombolytic locks in situations of recurrent CVC dysfunction.

Infections. CVC-related infections include exit site, tunnel, and CVC-related bloodstream infections (CRBSI), which are the most dangerous and can progress to life-threatening sepsis. The pathophysiology of CRBSI initiates from an extraluminal or intraluminal source. Typically, extraluminal sources of infection occur early on after CVC insertion (eg, bacterial contamination of a nonhealed exit site or tunnel), and the risk of intraluminal sources of bacteria persists as long as the CVC is in place. Intraluminal sources occur with CVC manipulation by health providers or home dialysis patients managing their own CVC: bacterial organisms from the external environment are transferred to the CVC lumen after breaches in aseptic no-touch or sterile techniques.

Diagnosis of CVC-related Infection

Case 2, continued: Our patient is treated for pneumonia, and HD is successfully initiated with a tunneled CVC placed via the right internal jugular vein. However, on the third treatment, he develops severe rigors, with a fall in blood pressure from 145/90 to 101/74 within 15 minutes of starting dialysis, and he becomes increasingly confused. The exit site is clean and intact. The dialysis nurse suspects he has a CRBSI.

Question 3: What are the most appropriate next steps in this case to confirm the diagnosis?

(a) Obtain 2 sets of blood cultures: 1 from catheter hub (red or blue) and 1 from the dialysis circuit line
(b) Culture the catheter exit site
(c) Obtain blood culture from a peripheral vein
(d) Begin antibiotics for presumptive CVC infection

For the answer to this question, see the following text.

CRBSI should be suspected in any patient with a HD CVC and signs and/or symptoms of a bacteremia after excluding alternative sources of infection. The signs and/or symptoms of CRBSI include fever, chills, new onset and unexplained fatigue, malaise, or altered level of consciousness. Hypotension and/or rigors within 15-20 minutes of initiating dialysis is consistent with endotoxin release from disruption of bacteria from the CVC surface caused by the increased blood flow through the CVC, and this should raise suspicion of a CRBSI, particularly when there is no clinical evidence for an alternate source. A thorough history and physical examination will help exclude alternative sources and may include appropriate cultures (urine, sputum, wound, or drainage collections), chest X-ray, or electrocardiogram.

Two sets of blood cultures should be obtained from the catheter (eg, hubs) and from the dialysis bloodline circuit or peripheral vein, so answer (a) is correct. In practical terms, the dialysis bloodline circuit is often preferred as the peripheral sample source because peripheral vein cultures are often challenging to obtain, may damage veins for future vascular access, and are more easily contaminated than the dialysis circuit. Both the dialysis bloodline circuit and peripheral vein are considered peripheral sources.

The diagnosis of CRBSI requires concurrent blood cultures positive for the same organism from 2 sites (ideally both catheter source and peripheral source) in the absence of an alternative source of infection. If there is apparent infection at the exit site or tunnel (eg, redness, pain, or discharge) then cultures should be taken from these sites as corroborative diagnostic data.

Question 4: To treat a catheter-related infection due to a nonvirulent pathogen, what is the most appropriate plan?

(a) Prescribe oral antibiotics and switch to intravenous antibiotics if there is no improvement.
(b) Initiate broad-spectrum antibiotics and narrow the coverage once culture data are available.
(c) Initiate broad-spectrum antibiotics, narrow the coverage once culture data are available, and exchange the CVC over a guidewire.
(d) Remove the CVC and utilize a nontunneled CVC for 5 days before placing another tunneled CVC.

For the answer to this question, see the following text.

Management of CVC-related Infection

The 2 components of treatment include management of the patient and management of the CVC (Fig 2). Once CVC infection is suspected, appropriate cultures of the exit site, tunnel, and/or blood should be obtained before initiating empiric antibiotics in order to properly identify the organism and determine antibiotic susceptibility. The choice of empiric broad-spectrum antibiotics depends on local dialysis facility policies and organism antibiotic sensitivities. Further refinement should occur with the culture sensitivity results to ensure effective treatment and to avoid antibiotic resistance, so the answer is (c). A hemodynamically unstable patient should be fluid resuscitated and transported to the hospital or emergency department for further care. If the unstable patient needs urgent dialysis, the CVC can be used once before its removal.

If stable, the patient can be managed in the outpatient setting. Management of the CVC depends on the type of CVC infection, the urgency for dialysis, the patient's symptoms and hemodynamic stability, the infecting organism, the infection history and risk factors, and the feasibility of CVC replacement. In general, there are 4 options for CVC management of CRBSI: (1) salvage with antibiotic lock; (2) CVC exchange over guidewire to preserve sites so long as the exit site and tunnel are not infected; (3) CVC removal with a new insertion at a separate site at the same time; or (4) CVC removal with a new insertion at a separate site after a CVC free period. This requires the temporary use of a nontunneled CVC to provide interim dialysis if needed.

If the infected CVC represents the last feasible vascular access option, then the patient should continue with the CVC with treatment by concurrent antibiotic lock and systemic antibiotics. If the CVC can be removed, it should be replaced by guidewire exchange to limit vessel damage and preserve vascular access options. If there is an exit site or tunnel infection, if the symptoms do not resolve after 48-72 hours of treatment with systemic antibiotics, or if the infecting organism is particularly virulent (eg, *Staphylococcus aureus* or fungal), then CVC removal with reinsertion of a temporary nontunneled CVC at a new site is indicated.

Ideally, repeat blood cultures should be negative before insertion of a new tunneled CVC. However, sometimes it is only feasible to have reinsertion at a new site at the time of removal. In such cases, evaluation for the presence of fibrin sheath (which is likely to be infected) and its disruption can remove the source of ongoing or future recurrent infection.

The duration of treatment depends on the infecting organism, with most requiring 2-3 weeks of systemic antibiotics. *S aureus*, fungal, and some Gram-negative organisms or polymicrobial infections require a minimum of 4 weeks or longer if there is associated metastatic infection (cardiac, lung, brain or bone). Thus, evaluation for metastasis with aggressive organisms, including two-

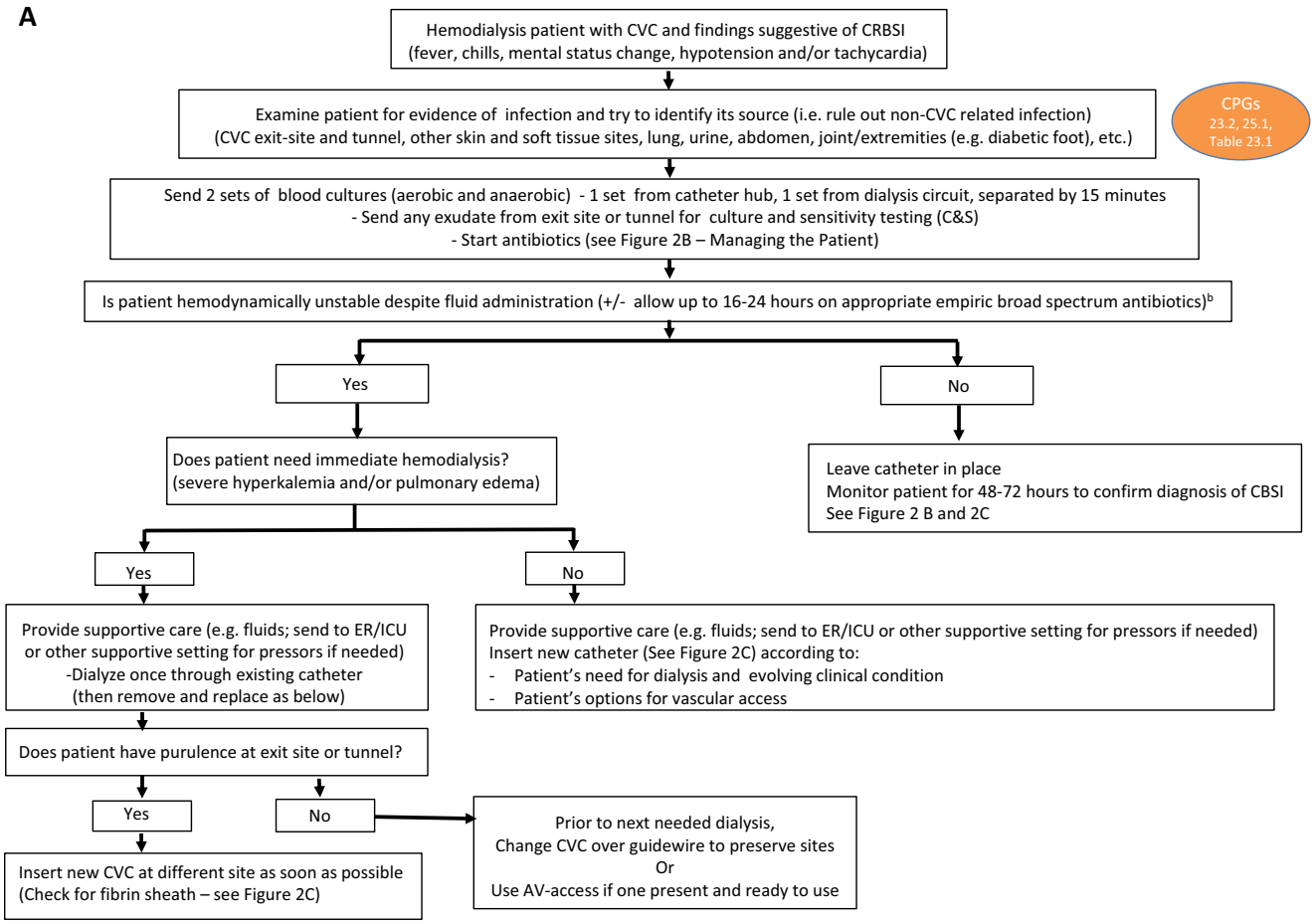
A
Hemodialysis patient with CVC and findings suggestive of CRBSI
(fever, chills, mental status change, hypotension and/or tachycardia)
Examine patient for evidence of infection and try to identify its source (i.e. rule out non-CVC related infection)
(CVC exit-site and tunnel, other skin and soft tissue sites, lung, urine, abdomen, joint/extremities (e.g. diabetic foot), etc.)
CPGs
23.2, 25.1,
Table 23.1
Send 2 sets of blood cultures (aerobic and anaerobic) - 1 set from catheter hub, 1 set from dialysis circuit, separated by 15 minutes
- Send any exudate from exit site or tunnel for culture and sensitivity testing (C&S)
- Start antibiotics (see Figure 2B – Managing the Patient)
Is patient hemodynamically unstable despite fluid administration (+/- allow up to 16-24 hours on appropriate empiric broad spectrum antibiotics)b
Yes
No
Does patient need immediate hemodialysis?
(severe hyperkalemia and/or pulmonary edema)
Leave catheter in place
Monitor patient for 48-72 hours to confirm diagnosis of CBSI
See Figure 2 B and 2C
Yes
No
Provide supportive care (e.g. fluids; send to ER/ICU
or other supportive setting for pressors if needed)
-Dialyze once through existing catheter
(then remove and replace as below)
Provide supportive care (e.g. fluids; send to ER/ICU or other supportive setting for pressors if needed)
Insert new catheter (See Figure 2C) according to:
- Patient's need for dialysis and evolving clinical condition
- Patient's options for vascular access
Does patient have purulence at exit site or tunnel?
Yes
No
Prior to next needed dialysis,
Change CVC over guidewire to preserve sites
Or
Use AV-access if one present and ready to use
Insert new CVC at different site as soon as possible
(Check for fibrin sheath – see Figure 2C)

Figure 2. (A) Immediate approach to suspected hemodialysis central venous CRBSI. (B) Manage the patient: empiric initial and subsequent antibiotic therapy for hemodialysis patient with suspected CRBSI. (C) Manage the catheter: catheter removal and replacement in hemodialysis patient with suspected CRBSI. [a]CPGs refers to KDOQI recommendations and associated tables. [b]According to local practice. [c]Or according to sensitivity report and local antibiotic availability. [d]Ability for "CVC free time" depends on local resources and feasibility as well as clinical considerations, such as ease of reinsertion after current CVC removed without guidewire exchange. [e]Send the old CVC tip for culture and sensitivity testing, if feasible, to confirm diagnosis of CRBSI. Abbreviations: CPGs, clinical practice guidelines; CRSBI, catheter-related bloodstream infection; CVC, central venous catheter; ER, emergency room; ICU, intensive care unit; IV, intravenous; US, ultrasound. Based on information in Lok CE, Huber TS, Lee T, et al. KDOQI clinical practice guideline for vascular access: 2019 update. *Am J Kidney Dis.* 2020;75(4)(suppl 2):S1-S164. doi.org/10.1053/j.ajkd.2019.12.001

dimensional (2D) echo for endocarditis, is essential, especially with *S aureus*–related CRBSI. Consultation with infectious diseases colleagues is recommended in such situations to guide antibiotic choice and duration.

Prevention of CVC-related Infection

A primary target of the new KDOQI guidelines for vascular access is to have a CRBSI rate of <1.5/1,000 CVC days. The best prophylaxis of CRBSI is not to have a CVC; however, this is often not feasible. CVC use should be limited to the shortest duration possible. Because CRBSI is associated with significant morbidity and mortality, proper prophylaxis against CRBSI is critical. To effectively implement a prophylactic strategy, 2 important points should be considered: (1) the baseline CRSBI rate in the facility as a benchmark to determine whether the prophylactic strategies are effective and (2) targeting the prophylactic strategy based on the pathophysiology of the CRSBI.

It should be a given that general universal precautions are in place and that health care providers and patients are aware of best practices for HD catheter care, including excellent hand hygiene. Specific strategies to prevent CRBSI target the extraluminal route by creating barriers to organism entry and disinfecting at the exit site, and those targeting the intraluminal route aim to "sterilize" the lumen or disrupt the catheter biofilm once organisms have entered.

Case 2, continued: The patient feels much better after starting dialysis and with treatment of his infection with

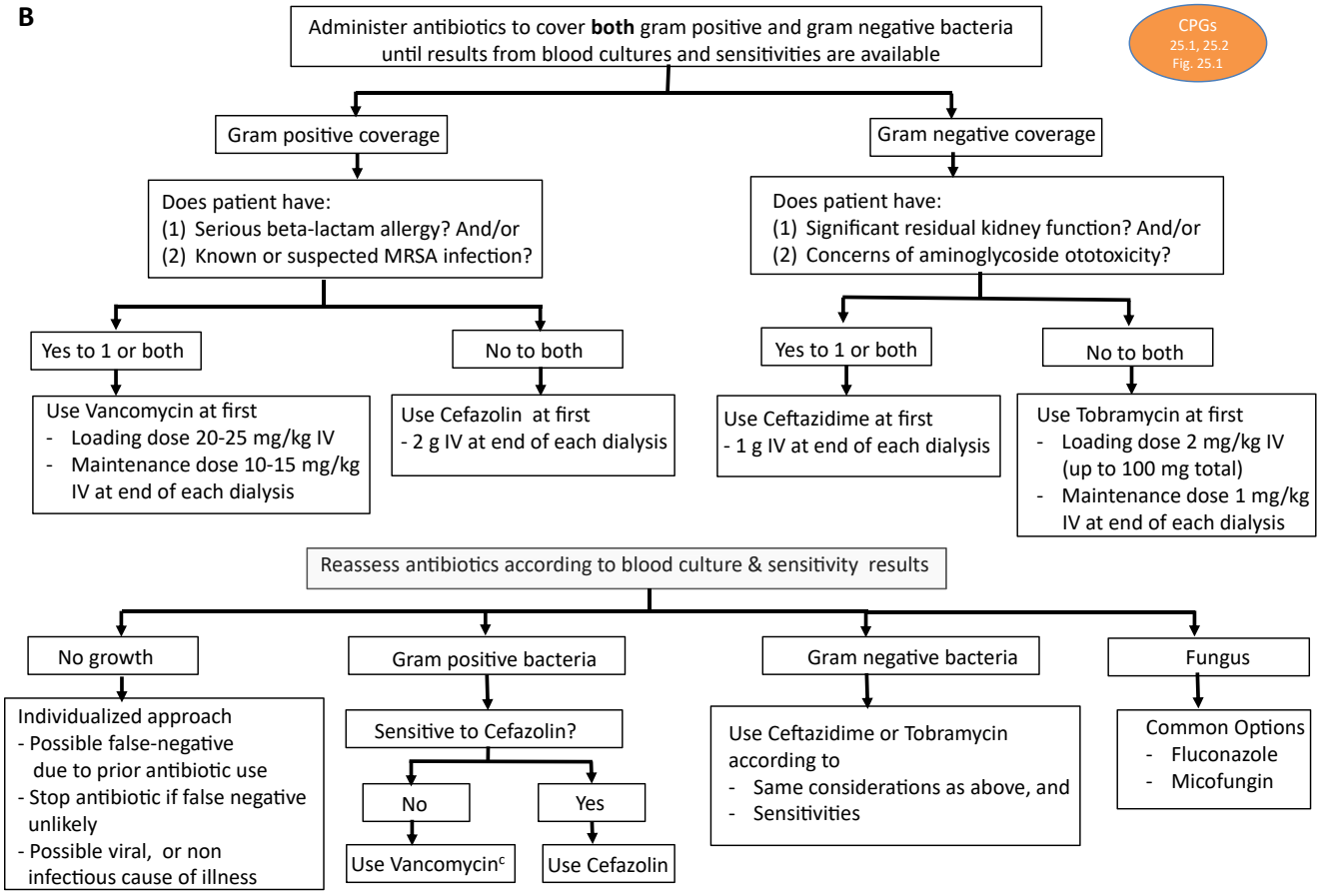
B
Administer antibiotics to cover both gram positive and gram negative bacteria until results from blood cultures and sensitivities are available
CPGs 25.1, 25.2 Fig. 25.1
Gram positive coverage
Gram negative coverage
Does patient have: (1) Serious beta-lactam allergy? And/or (2) Known or suspected MRSA infection?
Does patient have: (1) Significant residual kidney function? And/or (2) Concerns of aminoglycoside ototoxicity?
Yes to 1 or both
No to both
Yes to 1 or both
No to both
Use Vancomycin at first - Loading dose 20-25 mg/kg IV - Maintenance dose 10-15 mg/kg IV at end of each dialysis
Use Cefazolin at first - 2 g IV at end of each dialysis
Use Ceftazidime at first - 1 g IV at end of each dialysis
Use Tobramycin at first - Loading dose 2 mg/kg IV (up to 100 mg total) - Maintenance dose 1 mg/kg IV at end of each dialysis
Reassess antibiotics according to blood culture & sensitivity results
No growth
Gram positive bacteria
Gram negative bacteria
Fungus
Individualized approach - Possible false-negative due to prior antibiotic use - Stop antibiotic if false negative unlikely - Possible viral, or non infectious cause of illness
Sensitive to Cefazolin?
Use Ceftazidime or Tobramycin according to - Same considerations as above, and - Sensitivities
Common Options - Fluconazole - Micofungin
No
Yes
Use Vancomycin[c]
Use Cefazolin

Figure 2. (*continued*).

antibiotics. While his nurse is managing his catheter and "scrubs the hub" with chlorhexidine, he indicates that he would like to play a part in preventing future infections but is unsure how. At the end of dialysis, the nurse puts on a topical antibiotic ointment with his catheter dressing and explains that he should not get his dressing wet or dirty.

Question 5: This patient should be counseled regarding home CVC care and properly trained to actively participate to prevent future CVC-related infection with the following recommendations:

(a) Perform daily home dressing changes.
(b) Trim the dressing with scissors if the dressing lifts off the skin.
(c) Clean the CVC hubs with rubbing alcohol regularly.
(d) Keep the dressing and catheter dry.

For the answer to this question, see the following text.

Patients require careful training and instructions (eg, written protocol to refer to) to care for their CVCs at home. This includes keeping the dressing and CVC dry, answer (d). Patients receiving in-center HD should have an emergency dressing at home to replace the dressing in the event that the dressing becomes wet. When changing the dressing, patients should wear a face mask, wash their hands, and wear gloves. Patients should not open or clean the hubs unless trained in sterile or aseptic technique for home HD.

Several metanalyses have consistently found topical antibiotic or antiseptic barriers to be effective in reducing CRBSI. Such topical barriers include chlorhexidine sponge, povidone, medi-honey, mupirocin ointment, and Polysporin triple ointment. To target the intraluminal route of organism entry and CRBSI, interdialytic catheter lock solutions comprising various combinations of antibiotics or antimicrobials and anticoagulants have been evaluated for CRSBI prophylaxis (Table 2). The combinations with the most robust evidence include heparin/cefotaxime, heparin/gentamicin, and heparin/cotrimoxazole. Antimicrobial CVC caps and connectors have also been evaluated and shown to reduce CRBSI. Recently, the ClearGuard HD antimicrobial barrier cap was shown to lower the CRBSI rate more than Tego connectors plus Curos caps, but both groups demonstrated CRBSI rates < 1.0 per 1,000 CVC days.

Given the pathophysiology of CRBSI, the presence of fibrin sheath and intraluminal thrombus may act as a nidus for intraluminal sourced CRBSI. Therefore, efforts to reduce or eliminate intraluminal thrombus may also reduce infection risk. A randomized clinical trial has demonstrated that patients treated with interdialytic

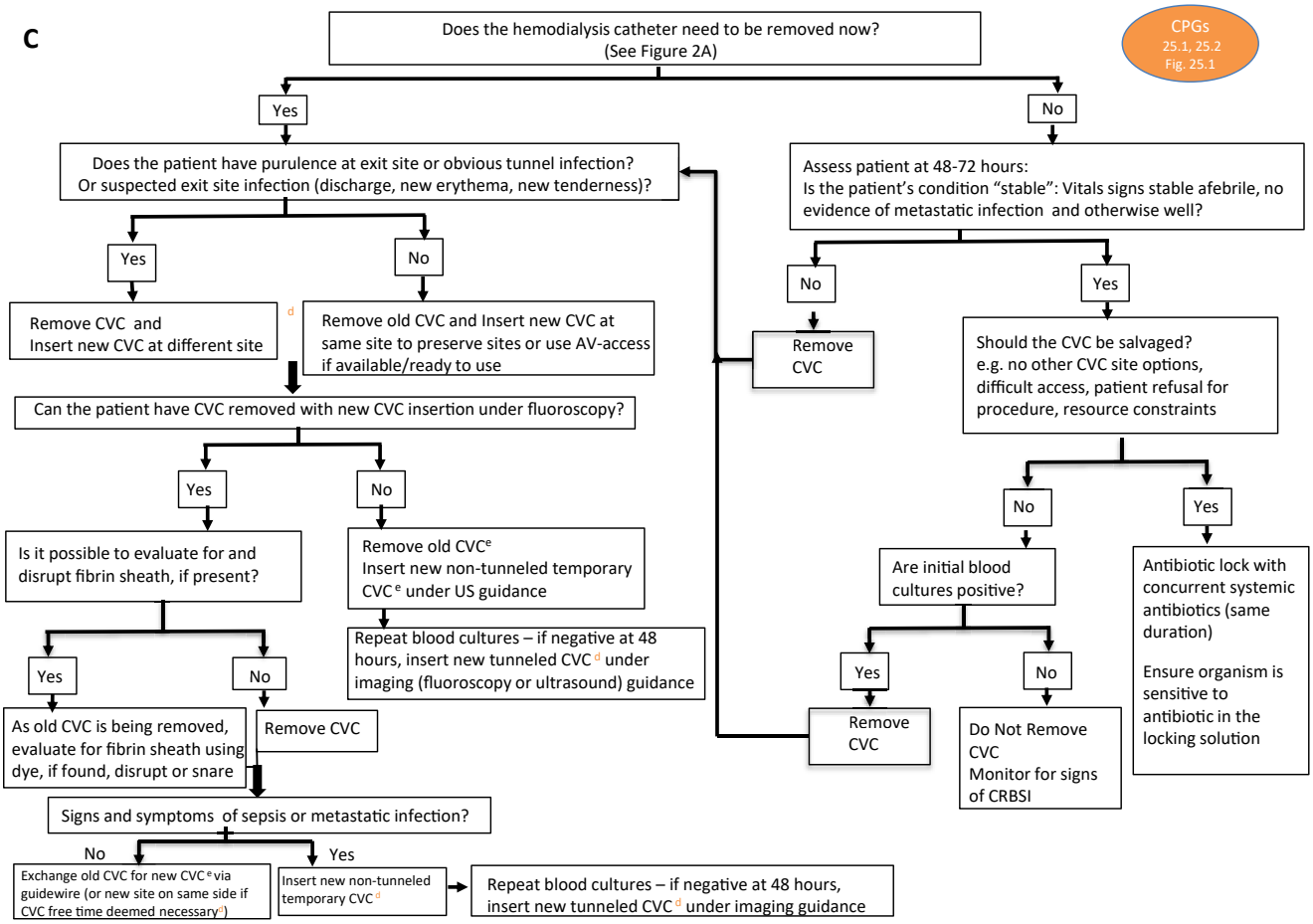
C
Does the hemodialysis catheter need to be removed now?
(See Figure 2A)
CPGs
25.1, 25.2
Fig. 25.1
Yes
No
Does the patient have purulence at exit site or obvious tunnel infection?
Or suspected exit site infection (discharge, new erythema, new tenderness)?
Assess patient at 48-72 hours:
Is the patient's condition "stable": Vitals signs stable afebrile, no evidence of metastatic infection and otherwise well?
Yes
No
No
Yes
Remove CVC and
Insert new CVC at different site
d
Remove old CVC and Insert new CVC at same site to preserve sites or use AV-access if available/ready to use
Remove CVC
Should the CVC be salvaged?
e.g. no other CVC site options, difficult access, patient refusal for procedure, resource constraints
Can the patient have CVC removed with new CVC insertion under fluoroscopy?
Yes
No
No
Yes
Is it possible to evaluate for and disrupt fibrin sheath, if present?
Remove old CVC e
Insert new non-tunneled temporary CVC e under US guidance
Repeat blood cultures – if negative at 48 hours, insert new tunneled CVC d under imaging (fluoroscopy or ultrasound) guidance
Are initial blood cultures positive?
Antibiotic lock with concurrent systemic antibiotics (same duration)
Ensure organism is sensitive to antibiotic in the locking solution
Yes
No
Yes
No
As old CVC is being removed, evaluate for fibrin sheath using dye, if found, disrupt or snare
Remove CVC
Remove CVC
Do Not Remove CVC
Monitor for signs of CRBSI
Signs and symptoms of sepsis or metastatic infection?
No
Yes
Exchange old CVC for new CVC e via guidewire (or new site on same side if CVC free time deemed necessary d)
Insert new non-tunneled temporary CVC d
Repeat blood cultures – if negative at 48 hours, insert new tunneled CVC d under imaging guidance

Figure 2. (*continued*).

locking with a thrombolytic - recombinant tissue plasminogen activator have lower rates of CRBSI; however, it may be a cost-prohibitive strategy for all patients with CVC and is often reserved for patients at high risk of recurrent CRBSI.

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➢ Lok CE, Huber TS, Lee T, et al. KDOQI clinical practice guideline for vascular access: 2019 update. *Am J Kidney*

Table 2. Antibiotic/Antimicrobial Lock Solutions for CRSBI Prophylaxis

Antibiotic or Antimicrobial	Relative Risk (95% CI)	CRSBI Rate	
		Without Lock Solution	With Lock Solution
Cefotaxime (3 RCTs)	0.42 (0.25-0.72)	67.5%	23.6%
Gentamicin (4 RCTs)	0.18 (0.07-0.46)	22.1%	4.0%
TPA, weekly (1 RCT)	0.30 (0.11-0.85)	Heparin only: 13%	Weekly TPA: 5%
Cotrimoxazole (1 RCT)	0.16 (0.04-0.69)	4.4 per 1,000 days	0.58 per 1,000 days
Methylene blue	0.29 (0.12-0.70)	0.82 per 1,000 days	0.24 per 1,000 days
Chlorhexidine (ClearGuard)	0.37 (0.20-0.68)	Tego + Curos: 0.75 per 1,000 days	ClearGuard: 0.28 per 1,000 days

Based on information in Table 24.1 of Lok CE, Huber TS, Lee T, et al. KDOQI clinical practice guideline for vascular access: 2019 update. *Am J Kidney Dis.* 2020;75(4)(suppl 2):S1-S164. doi.org/10.1053/j.ajkd.2019.12.001. Abbreviations: CRBSI, catheter-related bloodstream infections; RCT, randomized controlled trial; TPA, recombinant tissue plasminogen activator.

Dis. 2020;75(4)(suppl 2):S1-S164. doi:10.1053/j.ajkd.2019.12.001

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AV Access Complications

Maturation Failure, Stenosis, and Thrombosis

AV access maturation failure is defined as an AV access that, despite radiologic or surgical intervention (ie, endovascular or open procedural management), cannot be used successfully for dialysis by 6 months after its creation. Rates of AV access maturation failure have been reported to be 20%-60% in AVF and 5%-20% in AVG.

AVF maturation failure and AVG dysfunction are most commonly characterized on angiography by venous stenosis. In AVF, the venous stenosis frequently occurs at the juxta-anastomotic region, the region of the AVF adjacent to the vein-artery anastomosis, but stenoses can occur at cannulation segments and in the outflow of the AVF. In AVG, a stenosis occurs most commonly at the vein-graft anastomosis. In AVF maturation failure, the most common etiology of venous stenosis is secondary to flow-limiting intimal hyperplasia and inadequate outward remodeling (Fig 3). In AVG failure, the most common etiology of venous stenosis is secondary to aggressive intimal hyperplasia formation, characterized by the presence of myofibroblasts and an abundance of extracellular matrix components within the intima, leading to AVG thrombosis (Fig 3). Angiogenesis (neovascularization) within the adventitia layer and a macrophage layer lining the perigraft region are also present in AVGs, which is another major difference from the venous stenosis seen in AVF failure.

Currently, there are few effective therapies to prevent venous stenosis in AVF and AVG. Aspirin-dipyridamole and fish oil may provide primary patency benefit and reduce the need for interventions to maintain patency for AVGs. There are no other medications—including statins, warfarin, or other systemic agents—that have proven beneficial to avoid AV access dysfunction.

Case 2, continued: A few weeks later, the patient had an early cannulation forearm loop graft placed, with simultaneous removal of the CVC. Our patient is dialyzed via AV access, and he experiences prolonged bleeding after dialysis for 5 consecutive dialysis runs. The nurse reviews the

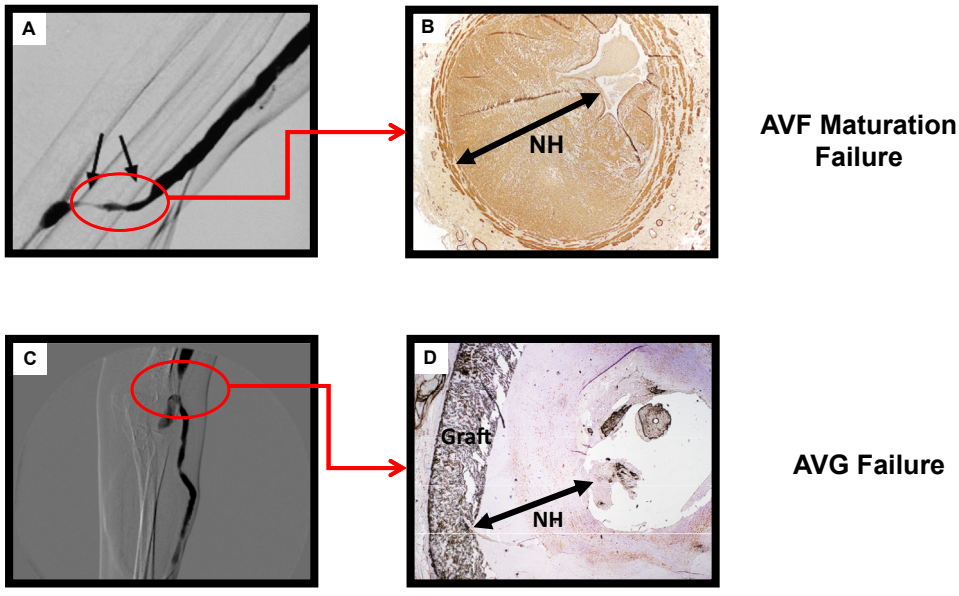

Figure 3. Angiography and histology of venous stenosis in AVF and AVG, with representative angiograms and histology of stenosis in a radiocephalic AVF (A and B) and AVG (C and D). (A) Venous stenosis is the common angiographic lesion seen in AVF maturation failure and AVG failure. Stenosis in AVF occurs most frequently in the juxta-anastomotic region of the AVF. In other types of AVFs, common areas of stenosis include the cephalic arch in brachiocephalic AVFs and proximal swing segment stenosis in transposed basilic vein transposition AVFs. (B) Intimal hyperplasia is the most common histological lesion present in AVF maturation failure. Stenosis in AVG occurs most commonly in the vein-graft anastomosis (C) with intimal hyperplasia being the most common histological legion present (D). Abbreviations: AVF, arteriovenous fistulas; AVG, arteriovenous grafts; NH, neointimal hyperplasia. Reproduced in modified form with the permission of the copyright holder (Wolters Kluwer Health, Inc.) from Lee T and Misra S. New insights into dialysis vascular access: molecular targets in arteriovenous fistula and arteriovenous graft failure and their potential to improve vascular access outcomes. *Clinical Journal of the American Society of Nephrology*. 2016;11(8):1504-1512. doi.org/10.2215/CJN.02030216

dialysis records and notes concurrent high venous pressures.

Question 6: What is most appropriate next step to confirm suspected AV access thrombotic flow-related dysfunction?

(a) Continue with physical examination (look, listen, feel—including an arm elevation test).
(b) Perform AV access surveillance via ultrasound dilution ("Transonic" evaluation).
(c) Arrange an angiography, with corrective treatment if causative lesion(s) are identified.
(d) Obtain a Kt/V measurement.

For the answer to this question, see the following text.

AV Access Monitoring and Surveillance

AV access (AVF or AVG) flow-related dysfunction, most commonly secondary to stenosis and thrombosis, occurs frequently during the lifetime of an AV access. The rationale for monitoring and supplementary surveillance is that detection of a vascular access abnormality (ie, stenosis) in AVF and AVG can lead to a pre-emptive intervention to correct a stenosis and prevent a vascular access thrombosis from occurring, and improve overall vascular access patency and function.

One important strategy of routine clinical monitoring is routine physical examination of the vascular access (Table 3). The main principles of physical examination include inspection, palpation, and auscultation of the vascular access to detect for signs of stenosis and pathologic abnormalities within the vascular access. Monitoring by physical examination can also be supplemented assessing trends in monthly dialysis adequacy studies (ie, reductions in Kt/V or urea reduction ratio without other cause), increasing venous pressures, and other clinical findings such as aspiration of blood clots, cannulation issues when previously not an issue, and prolonged bleeding after dialysis needle withdrawal (Box 2).

Surveillance utilizes specialized equipment and/or operators to detect stenosis. Several techniques measure AV access flow (Qa) including duplex ultrasound and ultrasound dilution. Dynamic and static venous pressure are also additional techniques for surveillance.

Clinical trials in AVG comparing routine clinical monitoring versus surveillance have largely demonstrated no difference in AVG survival with surveillance as compared with clinical monitoring. One study showed benefit of surveillance in AVG. In AVFs, there are few clinical trials studying monitoring versus surveillance. In these studies, surveillance in addition to clinical monitoring appears to increase the detection of stenosis but also increases the rate of interventions without improving patency. A recent randomized controlled trial (RCT) found no increase in interventions but also no difference in rate of or time to first thrombotic event of AVF and AVG. A systematic review and meta-analysis of RCTs assessed active AV access surveillance (by measuring Doppler flow or venous pressure) and pre-emptive correction of a newly identified stenosis versus routine clinical monitoring and deferred salvage, or pre-emptive correction of a known stenosis versus deferred salvage. In this meta-analysis, pre-emptive stenosis intervention for a functional AV access does not improve AV access patency. The main findings were that pre-emptive correction of an AV access stenosis may reduce the risk for thrombosis but not the risk for AV access loss. The treatment effects were larger in AVF as compared to the AVG group for both risk for AVF access loss and risk for thrombosis.

In this case, the clinical indicators of recurrent prolonged bleeding and concurrent elevated venous pressures should prompt confirmatory evaluation regardless of the Kt/V, so the answer is (c). Surveillance measures can be done for supplementary information but should not delay treatment.

Additional Readings

- Lee T, Misra S. New insights into dialysis vascular access: molecular targets in arteriovenous fistula and arteriovenous graft failure and their potential to improve vascular access outcomes. *Clin J Am Soc Nephrol*. 2016;11(8):1504-1512. doi:10.2215/CJN.02030216 ★ESSENTIAL READING
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Innovations in Vascular Access

Central Vein Access Innovations

Case 3: *A 45-year-old fashion designer initiated kidney replacement therapy on PD and remained on PD for 5 years but lost all residual kidney function. He had 2 episodes of peritonitis and struggled with volume overload, despite changes in his PD prescription. He received a living donor kidney transplant, which was complicated, required a prolonged stay in the intensive care unit, and had multiple CVCs. Consequently, he developed bilateral central vein occlusions. After 7 years with his kidney transplant, it is now failing.*

Question 7: Which of the following new technologies would be a first step to help our patient establish flow through his central veins?

Table 3. Routine AV Access Monitoring and Clinical Indicators by Physical Exam

Examination	Fistula (Normal)	Graft (Normal)	Flow-related Dysfunction or Poor Maturation (Abnormal)	Infection, Steal Syndrome, or Aneurysm/ Pseudoaneurysm (Abnormal)
Look	• Well-developed main venous outflow, no irregular/dilated areas or aneurysm formations, adequate areas of straight vein that can be used for 2-needle, rope-ladder cannulation. • Vessel collapses when arm is elevated above head.	• Uniform-sized graft in a loop or straight configuration • No irregular areas or aneurysm or seroma formations with organized site rotation used for cannulation	AVF • Poor maturation • Multiple venous outflow veins (accessory or collateral veins) • Poorly defined cannulation areas Stenosis • Can occur in artery or any venous outflow vein • Look for a narrowing of the outflow vein, abnormal pulsations, or aneurysm formations • Vessel does not collapse with arm elevation AVF or AVG • Dilated neck veins or surface collateral veins in the arm or neck above the vascular access	Infection • Redness, swelling, induration, drainage, or pus Steal syndrome • Extremity/hand mottling or discoloration • Skin ulceration due to poor arterial blood flow to the hand • Check nail beds, fingers and hand for unusual skin changes Aneurysm • Abnormal areas of dilatation with overlying shiny skin or skin thinning
Listen with a stethoscope	Low-pitch continuous diastolic and systolic components	Low-pitch continuous diastolic and systolic components	High-pitch discontinuous systolic component only	Steal syndrome • AVF may have a very strong bruit
Feel with your fingers or palm	• Thrill at the arterial anastomosis and throughout the entire outflow • Vein that is easy to compress • Pulse augmentation	Thrill strongest at the arterial anastomosis but should be felt over entire graft and be easy to compress	AVF • Pulse at the site of a stenotic lesion—may be water-hammer in quality and feel • Lack of pulse augmentation (inflow stenosis) AVG • Thrill and/or pulse strong at the site of stenotic lesion • Pulse has a water-hammer feel • An AVG with a low intra-access blood flow feels mushy • Local area of the graft that feels mushy or irregular in shape can be a site of aneurysm formation	Infection • Warm or painful to touch, swelling • Wet from drainage Steal syndrome • Feel bilateral limbs (hands and fingers) and compare for the access limb to be the same as the non-access limb • Compare temperature, grip strength, and range of motion and any complaints of changes in sensation or pain • If the access limb has any major differences than the nonaccess limb, consider steal syndrome

Based on information in Table 13.1 of Lok CE, Huber TS, Lee T, et al. KDOQI clinical practice guideline for vascular access: 2019 update. *Am J Kidney Dis.* 2020;75(4)(suppl 2):S1-S-164. doi.org/10.1053/j.ajkd.2019.12.001.

(a) Hemodialysis Reliable Outflow (HERO) graft
(b) EndoAVF
(c) Bioengineered graft
(d) Surfacer device

For the answer to this question, see the following text.

In a majority of patients, HD will be part of their ESKD Life-Plan, even if PD and transplant are active modalities. A functional, reliable, and sustainable vascular access is essential for HD therapy. Planning for HD vascular access should occur when a patient is failing their kidney transplant or PD modality, as has occurred to the patient in Case 3. Kidney transplant patients should follow the same guidance as CKD patients and should be referred for vascular access when their eGFR falls to 15-20 mL/min/1.73 m^2. Guidance for when to refer for vascular access in a patient failing PD is in Box 3.

Box 2. Examples of Clinical Indicators of AV Access Flow Dysfunction Noted at Dialysis Session

- New difficulty with cannulation when previously not a problem
- Aspiration of clots
- Inability to achieve the target dialysis blood flow without other cause
- Prolonged bleeding beyond usual for that patient (eg, >15 minutes) from the needle puncture sites for 3 consecutive dialysis sessions
- Persistently elevated venous pressures without other cause
- Unexplained (>0.2 units) decrease in the delivery dialysis dose (Kt/V) on a constant dialysis prescription without prolongation of dialysis duration

Although the current and preferred vascular access remains the traditional surgical upper extremity AV access, it may be difficult or prohibited by bilateral central vein occlusions. Central venous occlusion is an important later complication of CVC use that must always be considered when choosing to insert a CVC; this highlights the importance of using CVC exchange over a guidewire at the same site, whenever possible, to preserve central veins from damage and occlusion. There have been several recent novel innovations in devices and technology for HD vascular access care, including those that consider such challenges when bilateral central venous occlusion occurs. These innovations can be divided into several categories: (1) new vascular access creation, (2) maintenance of vascular access patency, and (3) future innovations in the pipeline. The innovations for new vascular access creation (AVF and AVG) include (1) endovascular AVF creation, (2) bioengineered grafts, (3) early cannulation grafts, and (4) hybrid devices.

Box 3. Indications for Referral for Hemodialysis Vascular Access in PD Patients

- Recurrent peritonitis, especially if due to persistent poor connection technique (Gram-positive) or bowel leak (mixed Gram-negative)
- Ultrafiltration failure, especially in the presence of oliguria or anuria and persistent volume overload
- Decline in physical status considered to be the result of underdialysis (adherence issues or loss of residual kidney function)
  - o Note: This is a relative indication and should not be construed as implying that loss of residual kidney function is itself an indication for vascular access creation.
  - o Caution: The patient nonadherent to PD may very well be nonadherent to HD and vascular access creation.
- Change in status of the patient such that self-dialysis is no longer feasible (eg, serious intercurrent life event, such as stroke, death, or other loss of a caregiver)
- Significant noninfectious complication (eg, recurrent hernias, dialysate leaks including hydrothorax not amenable or refractory to treatment)

Based on information in Table 6 of: Lok CE, Huber TS, Lee T, et al. KDOQI Clinical Practice Guideline for Vascular Access: 2019 Update. *Am J Kidney Dis.* 2020;75(4)(suppl 2):S1-S164. doi.org/10.1053/j.ajkd.2019.12.001
Abbreviations: HD, hemodialysis; PD, peritoneal dialysis.

In this specific case presented, several devices may be potentially applicable for this patient's central vein occlusions. Of note, complete central venous occlusion prohibits successful AV access creation and use, and until recently could not be bypassed. In 2020, the US Food and Drug Administration (FDA) approved a new device referred to as "Surfacer,", which allows for insertion of a dialysis catheter in the right supraclavicular region of patients with right-sided central vein occlusion, answer (d), by obtaining vascular access "inside to out". In short, procedurally, under fluoroscopy after obtaining access to the right femoral vein, a stiff metal sheath is passed superiorly into the right atrium, and a new tract is created through the soft tissues in the chest, bypassing the occluded thoracic central vein segment on the right side of the body. A central catheter (HD CVC or CVC component of a HERO graft) can then be placed by Seldinger technique over the wire in the tract created. Careful patient selection and an experienced operator are critical because the device is not steerable; hemorrhagic complications have occurred and can be fatal. In a multicenter study performed in Europe, this novel device demonstrated a 97% success rate with achieving central venous access and dialysis catheter placement.

Another late-stage vascular access option for patients receiving HD with limited venous anatomy is the Hemodialysis Reliable Outflow (HERO) device. This device is a hybrid-graft catheter (polytetrafluorethylene [PTFE] graft connected to a silicone catheter venous outflow component) that is implanted subcutaneously. The device can be inserted through stenotic but patent central vein segments in patients with suboptimal peripheral veins and terminates in the right atrium. Studies have demonstrated the technical feasibility of placement of the HERO device and comparable results in terms of patency to standard PTFE grafts; when compared with dialysis catheters, HERO had better patency, fewer interventions, and lower infection rates.

AV Access Innovations

Although not applicable to the current case, recent innovations in vascular access creation may be options for consideration in the appropriate patient. Traditionally, creation of AVF has been performed using an open surgical technique. Recent innovations in AVF creation have included minimally invasive endovascular techniques in the mid-forearm (endoAVF).

There are currently 2 approved FDA devices using a catheter-based system, Ellipsys (Medtronic) and WavelinQ (BD Bard), that create a side-to-side anastomosis with the deep vessels (eg, perforator vein, proximal ulnar or radial arteries) located in the proximal to mid-forearm. In a prospective single-arm study in 107 patients using the

Ellipsys device, with the primary end points being brachial artery flow > 500 mL/min and AVF luminal diameter > 4 mm, 105 patients had AVFs created; 92 out of 107 patients (86%) achieved the primary outcomes. In another pivotal single-arm study, the Novel Endovascular Access Trial (NEAT), the Everlinq system (now the WavelinQ system) was used to create endoAVFs in 59 out of 60 patients; a successful AVF was created in 87% of patients, with those patients achieving a mean brachial artery flow in AVF of 918 mL/min and mean AVF lumen diameter of 5.2 mm. Furthermore, the latter study reported a primary and cumulative patency at 1 year of 69% and 84%, respectively. Real-world studies suggest equivalent outcomes between surgical and endovascularly created AVF, though the endoAVF requires more secondary interventions to obtain functional patency.

PTFE has been the standard biomaterial used for AVGs. PTFE grafts suffer from high rates of loss of primary unassisted patency at 1 year (~75%) and recurrent stenosis and thrombosis. Recent innovations have included the development of bioengineered human acellular vessels (HAVs), that are mechanically durable and immunologically inert. The concept is that tissue engineered conduits are generated by seeding human vascular cells onto a biological scaffold that are cultured to form tissue. During the incubation process, the cells generate extracellular matrix; subsequently the polymer scaffold degrades, thus producing a biological vessel that simulates a human blood vessel. In 2016 phase 2 studies from the Humacyte HAV in 60 patients with kidney failure requiring HD demonstrated 6- and 12-month primary patency of 63% and 28%, respectively, and secondary patency of 97% and 89%, respectively. HAVs were evaluated in multicenter phase 3 clinical trials in patients with kidney failure requiring HD with results pending, comparing outcomes with standard PTFE and AVFs.

AV Access Corrective Interventions to Maintain Patency

Although future innovative AV access solutions are promising, recurrence of stenosis, especially juxta-anastomotic stenosis, currently remains the most common cause of AV access dysfunction. For years, the standard treatment of AV access dysfunction has been standard balloon angioplasty (percutaneous transluminal angioplasty [PTA]), which has been shown to induce endothelial injury leading to intimal hyperplasia. New technology such as drug-coated balloons (DCB) combined with standard PTA and endovascular stent grafts has been shown in RCTs to prolong patency. DCBs deliver an antiproliferative therapy (eg, paclitaxel or sirolimus) to prevent intimal hyperplasia after PTA. A recent landmark clinical trial demonstrated that angioplasty with DCB was superior to standard PTA when evaluating the primary outcome of treatment of stenotic lesions in dysfunctional AVF during the 6 months after the procedure. Subsequent RCTs and meta-analysis have had conflicting results, suggesting that longer term follow-up and experience are required to determine the role of DCBs in vascular access management.

Stent grafts are a self-expanding vascular prothesis composed of PTFE encapsulating a nitinol stent scaffold. Stent grafts have been shown to improve the primary patency of the target lesion of the vascular access as compared with standard PTA. An early large multicenter clinical trial in 190 patients with dysfunctional AVG with stenosis at the venous anastomosis demonstrated that stent-grafts, as compared with standard PTA, improved patency at 6 months with fewer repeat interventions. Subsequent meta-analyses supported this finding and extended its benefit to longer durations.

Promising new innovations in the pipeline may positively impact AV access outcomes. For example, the VasQ (Laminate Medical Technologies) device manipulates the anastomotic angle and geometry to reduce vein wall tension and control flow patterns. Another technology is perivascular delivery of a drug such as nitric oxide that can promote outward remodeling and inhibit intimal hyperplasia. Other technologies, such as those to facilitate the monitoring of AV access, are being evaluated.

Finally, the average survival (cumulative patency) of AVF and AVG are difficult to determine due to limited comparative studies, era effects, the impact of a prior "one-size-fits-all fistula" approach (ie, poorer outcomes for AVF in patients who were not suitable for AVF and poorer survival of AVG due to loss or operator skill, etc), study biases and confounding, and impact of new technologies. The future will inform us with upcoming RCTs, the refreshing approach to selective use of AVF or AVG, and incorporation of innovative technology.

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Uncommon but Important Vascular Access Situations

Case 4: *A 61-year-old painter has a left upper arm AVF. He self-cannulates for home nocturnal dialysis (5 nights per week, 5-6 hours per night). For ease of cannulation, he utilizes an "area" technique, as opposed to a "rope ladder." He has had multiple prior AV accesses and has been on HD for 8 years. His AVF is aneurysmal, and he recently underwent a fistulogram which disclosed an outflow stenosis. He uses a topical hemostatic agent (eg, Gelfoam or Surgicel) to assist with hemostasis. He notices that the skin around the cannulation zone is becoming sore and that skin is often removed with the topical agent. A scab has formed (Fig 4A), which falls off spontaneously at home (Fig 4B); he also notices a pulsation deep in the wound (video). He is worried and seeks evaluation at his local hospital's emergency department. While he is waiting to be seen, the AVF ruptures.*

Question 8: Which of the following increased the risk of AVF rupture in this case?

(a) Frequent nocturnal dialysis
(b) Area cannulation (as opposed to rope ladder cannulation)
(c) Angiogram evaluation
(d) Prolonged dialysis treatments

Question 9: Which of the following techniques would *not* be appropriate to address a bleeding AV access?

(a) Direct pressure on the bleeding site using a finger (ie, digital pressure)
(b) Direct pressure using a bottle cap with the hollow side toward the skin.
(c) Tourniquet application proximal to the bleeding point (ie, closer to the body)
(d) Tourniquet application distal to the bleeding point (ie, farther from the body)

Question 10: Which of the following is an appropriate reason for urgent referral (within 1 week) to a vascular access surgeon?

(a) Development of a dry scab over the AV access within the past week
(b) Elevated venous pressures noted on HD, but adequate clearance

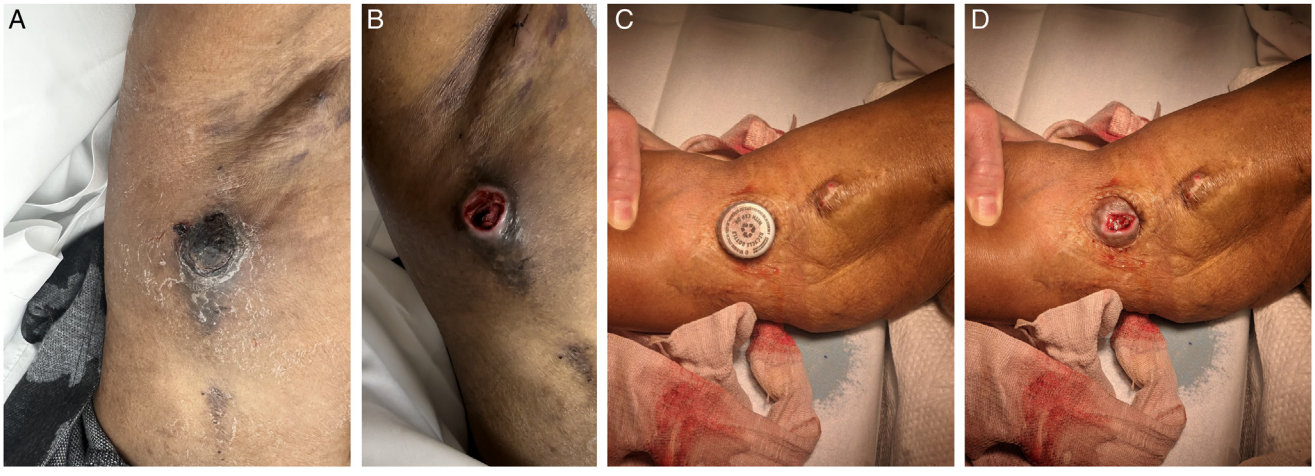

Figure 4. (A) Scab overlying an arteriovenous access at a cannulation segment. (B) Scab removed, revealing the underlying vessel. (C) Bottle cap technique to obtain hemostasis, with the hollow side pressed firmly toward the skin (Courtesy of John Lucas, MD). (D) Bottle cap removed, with inflow control obtained via digital pressure, demonstrating the underlying ulceration (Courtesy of John Lucas, MD).

(c) Elevated arterial pressure noted on HD, with inability to achieve the prescribed pump flow rates, but adequate clearance
(d) Evaluation of a long-standing (ie, greater than 1 year), large, disfiguring AVF

For the answers to these questions, see the following text.

Vascular Access Hemorrhage

Fatal vascular access hemorrhage (FVAH) is a rare but dramatic and catastrophic complication of AV access. Successful management and prevention are of highest concern for both the patient and the dialysis and vascular access care team. The risk factors for FVAH include AV access-related complications such as difficulty with cannulation or poor flow characteristics, in addition to the development of concerning physical examination findings (Table 4). In this case, use of a clotting material over the cannulation site caused fragile skin to adhere to the material and pull off part of the scab upon its removal, risking bleeding. Furthermore, use of an area cannulation technique without adequate site rotation as opposed to the preferred rope ladder technique has also been associated with poor outcomes; the answer to Question 8 is thus (b). Both AVF and AVG can be involved in FVAH; the relative risk of one form of AV access over the other is unclear. FAVH can occur with all types of HD and in all geographic locations—in-center, satellite, and home HD. These events frequently occur outside the dialysis unit, with profound blood loss evident at the scene. This can lead to first responders sometimes mistakenly concluding that a homicide or a suicide has occurred.

The first step to management is direct pressure over the bleeding orifice. This may be inadequate, and use of a tourniquet can be lifesaving. Critically, the tourniquet must be placed above the bleeding point, and it must be tightened to above systolic blood pressure to stop the flow through the AV access; thus, the answer to Question 9 is (c). Inadequate tension will be ineffective and may actually increase the blood loss because any venous return is obliterated while arterial flow is still present. As such, it may be challenging for a patient to find an appropriate tourniquet, be it a rope or belt, to exert the required force. Furthermore, successful cessation of arterial flow will lead to the affected limb becoming ischemic and may lead to limb loss without emergent assistance. It must be highlighted that AV access rupture is a medical and surgical emergency that requires immediate professional attention.

Until medical help is available, use of a carefully placed bottle cap before full rupture has been described. It is important to note that the hollow side is used over the bleeding orifice, and firm pressure is required to obtain hemostasis, which can be uncomfortable for the patient (Fig 4A-B). It is critical to underline that rapid surgical evaluation is required: this is only a temporizing measure, and the AV access will rapidly bleed again once the cap is removed.

Prevention is key, so it is critical to recognize the signs of imminent AVF rupture, such as necrotic scabs (Fig 4C-D; Video 1) or suppurative puncture sites; thus, the answer to Question 10 is (a). If these signs are present, it is important to immediately refer the patient to surgery for evaluation. AV accesses with aneurysms or pseudoaneurysms are at particularly high risk of rupture when they are associated with concerning physical examination findings. These are outlined in the 2019 KDOQI guidelines (Table 4). Of note, size by itself is not considered to be a risk factor, as nonaneurysmal AV accesses can also rupture. Although a large aneurysmal AVF ("megafistula") without concerning physical examination signs can be safely monitored in terms of rupture, their inevitably high flow rates may be associated with cardiac issues. Thus, both AV access and cardiac status should be monitored carefully and referred for revision (ie, flow-reduction surgery) or ligation as needed.

Additional Readings

➢ Ellingson KD, Palekar RS, Lucero CA, et al. Vascular access hemorrhages contribute to deaths among hemodialysis patients. *Kidney Int.* 2012;82(6):686-692. doi:10.1038/ki.2012.185 ★ESSENTIAL READING
➢ Gill JR, Storck K, Kelly S. Fatal exsanguination from hemodialysis vascular access sites. *Forensic Sci Med Pathol.* 2012;8(3):259-262. doi:10.1007/s12024-011-9303-0

Table 4. Physical Findings of Urgent Versus Nonurgent Aneurysms/Pseudoaneurysms

Physical Exam Findings	Nonurgent: Monitor Closely	Urgent: Quick Action Needed
Skin quality	Overlying skin is supple and easily pinched	Overlying skin is thin, shiny, and/or depigmented
Skin erosion	None, skin is intact	Ulcers, scabs
Visible, pulsating vessel underlying skin	Absent	May be seen
Bleeding from cannulation sites	Uncommon	Often prolonged
Arm elevation test	Fistula collapses	Fistula may not collapse
Change in size	Slow change or increase in size	Rapid change or increase in size

Based on information in Table 17.1 of Lok CE, Huber TS, Lee T, et al. KDOQI clinical practice guideline for vascular access: 2019 update. *Am J Kidney Dis.* 2020;75(4)(suppl 2):S1-S164. doi.org/10.1053/j.ajkd.2019.12.001.

➢ Goolsby C, Rojas LE, Andersen M, et al. Potentially survivable fatal vascular access hemorrhage with tourniquet use: a post-mortem analysis. *J Am Coll Emerg Physicians Open*. 2020;1(6):1224-1229. doi:10.1002/emp2.12201
➢ Jose MD, Marshall MR, Read G, et al. Fatal dialysis vascular access hemorrhage. *Am J Kidney Dis*. 2017;70(4):570-575. doi:10.1053/j.ajkd.2017.05.014
➢ Whitehill C. Put a lid on it—managing life-threatening bleeds from fistulas and grafts. *Kidney Matters* 2019;7:14-16. https://www.kidneycareuk.org/about-kidney-health/treatments/dialysis/put-lid-on-it/ ★ESSENTIAL READING

Case 5: *A 63-year-old real estate agent with kidney failure due to hypertensive nephrosclerosis has been on HD for 6 years, first with a left forearm fistula and now with a left brachiocephalic fistula. Over the past 2 months he has become increasingly short of breath, especially on exertion, and he has noticed a corresponding reduced overall exercise tolerance. The patient indicates that there is an annoying "whooshing noise" in his ear, "like the sound of waves lapping in the ocean." There is no paroxysmal nocturnal dyspnea, orthopnea, or extremity edema. There is no history of respiratory illness, and the patient has not had any documented cardiovascular events. On examination, the patient is afebrile with a blood pressure of 155/95 mm Hg, heart rate of 110 bpm, and respiratory rate of 14 breaths per minute. Further investigations reveal that the flow through the AVF (Qa) is 2.8 L/min. In addition to finding pulmonary hypertension, the patient's cardiac output is 10.1 L/min but reduced to 7 L/min with occlusion of the AVF. The patient has a procedure to reduce the flow through the AVF, and the symptoms resolved.*

High Cardiac Output Heart Failure

The increased flow associated with AV access creation can significantly influence cardiac hemodynamics and lead to structural and functional cardiovascular abnormalities. For example, it can lead to high cardiac output (CO) with subsequent heart failure and pulmonary hypertension. In patients with KF requiring HD, approximately 25% of cases of high output heart failure can be attributed to AV access. Due to the higher access flows (Qa) in the upper arm versus forearm AVF (ie, approximately double Qa in the upper arm), high output cardiac failure occurs more commonly with the higher flow upper arm AV access.

This is important to consider when developing the patient's ESKD Life-Plan and Access Plan. For example, in an elderly patient who has limited life expectancy and is at high risk of AVF failure due to the presence of poor vasculature and heart failure, one might consider an upper arm AVF because upper arm vessels are typically larger than forearm vessels and an upper arm AVF might have a higher likelihood of AVF maturation success. The consideration of "preserving vessel real estate" is not as critical because the patient has limited life expectancy, so the priority is getting functional, "complication-free" vascular access quickly. However, in this situation, the patient has underlying heart failure, so the vascular access implications must be carefully considered.

First, an AVF may not mature, even if created in the upper arm. In order for an AVF to mature, not only does it require good inflow (ie, not by a calcified, diseased, or damaged artery) and unobstructed, patent venous outflow, it requires a good pump (cardiac function) to provide the good inflow and pressure required for AVF maturation. Further, an upper arm AVF with high flow (eg, >2 L/min) created in a patient with established heart failure may worsen the pre-existing heart failure.

It is useful to have a baseline cardiac 2D echo to inform the operator because it may influence the type or location of vascular access and provide the nephrologist with a reference in case the patient develops future signs or symptoms of heart failure. Indeed, when otherwise stable HD patients develop signs or symptoms of heart failure, the nephrologist should consider the AV access as a potential contributing factor.

The use of routine cardiac 2D echo in addition to vigilant monitoring of signs and symptoms of heart failure may be helpful in detecting high flow cardiac failure. High flow cardiac output has been associated with Qa/CO > 20%. There are other 2D echo parameters used to guide the monitoring and management of high flow AV access such as right ventricular longitudinal strain. As discussed previously, flow reduction techniques and possibly AV access ligation may be necessary. Such important discussions must be made together with the patient and the dialysis and vascular access teams. The discussion should include alternative access treatments and potential future kidney replacement modalities and associated accesses because the loss of an AV access is the loss of one of the patient's lifelines for HD.

Additional Readings

➢ Askary ZM, Abdelhady M, Yousef MA, Mohammed AK. Influence of native upper limb hemodialysis arteriovenous fistula on left ventricle. *Ital J Vasc Endovasc Surg*. 2022;29(2):70-73. doi:10.23736/S1824-4777.22.01532-7
➢ Roca-Tey R. Permanent arteriovenous fistula or catheter dialysis for heart failure patients. *J Vasc Access*. 2016;17(suppl 1):S23-S29. doi:10.5301/jva.5000511 ★ESSENTIAL READING
➢ Saleh MA, El Kilany WM, Keddis VW, El Said TW. Effect of high flow arteriovenous fistula on cardiac function in hemodialysis patients. *Egypt Heart J*. 2018;70(4):337-341. doi:10.1016/j.ehj.2018.10.007

Supplementary Material

Supplementary File (PDF)

Video 1. Exposed vessel threatening impending rupture.

Article Information

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